Cross-flow filtration with different ceramic membranes for polishing wastewater treatment plant effluent

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CROSS-FLOW FILTRATION WITH DIFFERENT CERAMIC MEMBRANES FOR POLISHING WASTEWATER TREATMENT PLANT EFFLUENT

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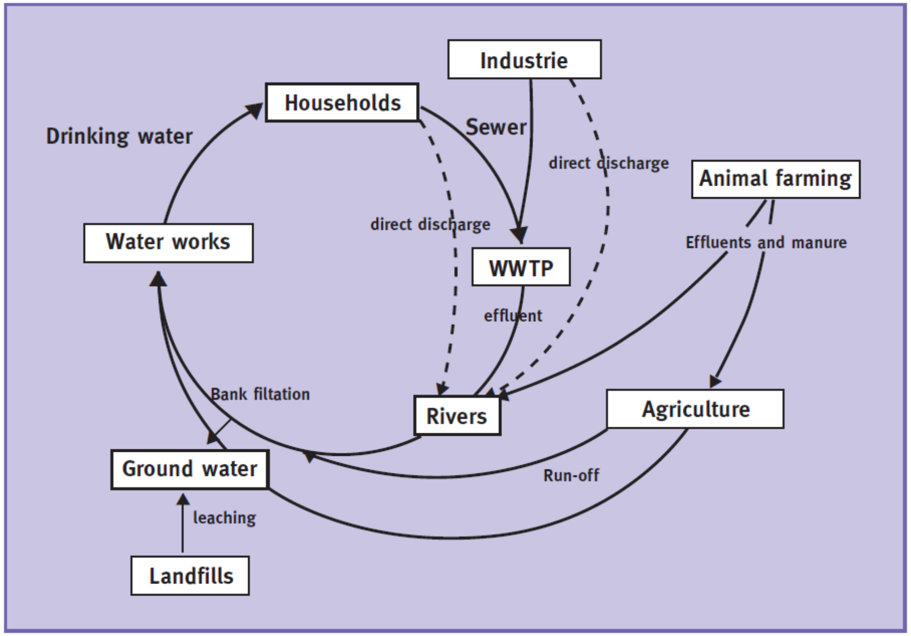
AALBORG UNIVERSITY
DENMARK

Outlook

- ❑Problem and Hypothesis
- ❑Materials and Methods
- ❑Results and Discussion
- ❑Conclusion

Challenge

- Micro/nano–pollutants in wastewater are a challenge to wastewater professionals. The presence of contaminants in **w**aste **w**ater **t**reatment **p**lant (**WWTP**) effluents may cause a severe risk for the drinking water preparation. The effluent cannot be simply discharged to environment because it contains toxic ions and organic micro-pollutants which are harmful for aquatic organism.



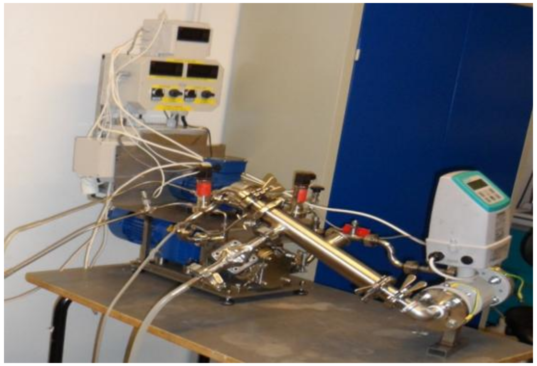
Challenge

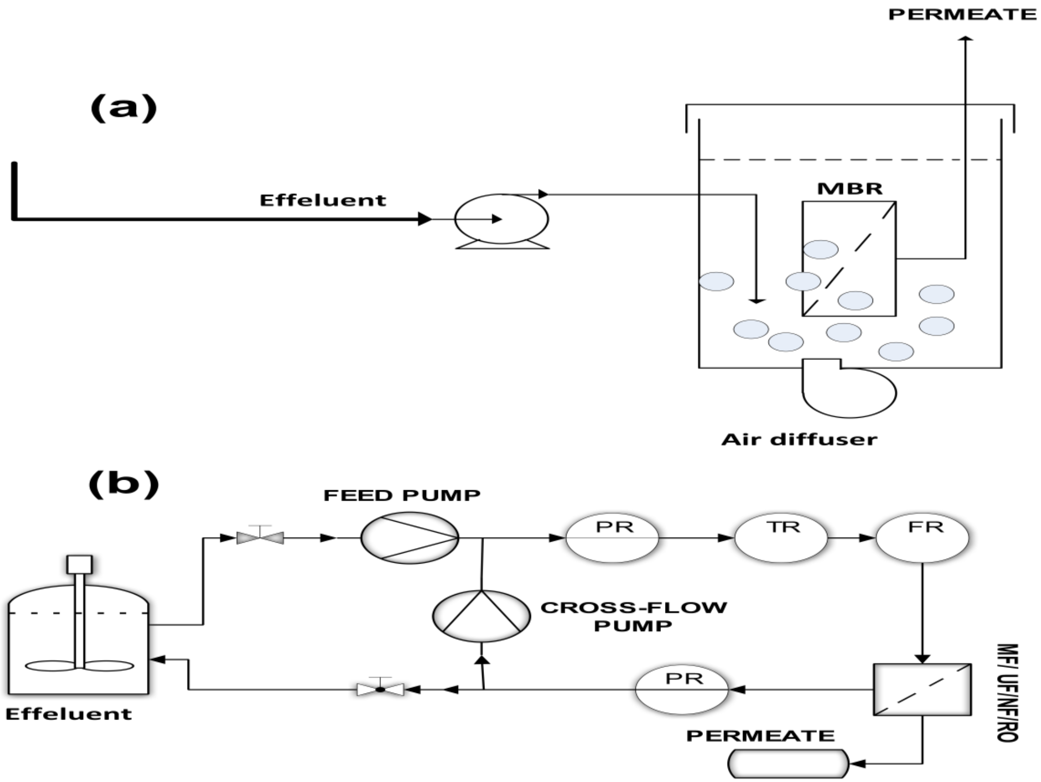
Compounds	Examples	Detected in Denmark WWTP*	Detected in EU/US WWTP**
Organic Contaminants from Industrial sources	Sulfonated organic compounds, MTBE	▲	▲
Household and personal care products	Sunscreen Agents	▲	▲
Pharmaceuticals	Acetaminophen, Ketoprofen, Ibuprofen, Diclofenac		▲
Party drugs	Defattening pills, Viagra, XTC	▲	▲
Pesticides	Glyphosate		▲
Metal Ions	Cu, Pb, Zn, Cd, Cr, Hg	▲	▲

***Punktkilder 2012, Miljøministeriet, www.nst.dk (in Danish).**
**** Pollutants in urban waste water and sewage sludge, European Commission Report 2011, www.europa.eu.int**
*****Municipal WWTP Effluents, RIWA Report 2007, The Netherland.**

Hypothesis

- A possible strategy to avoid this is to polish the effluent by membrane processes.





Materials and Methods

- ***Sample.*** The samples were taken from Aalborg WWTP which is located in the west of Aalborg city, Denmark.

- ***Filtration.*** The effluent was pumped at 6 bar to a cross-flow filtration.

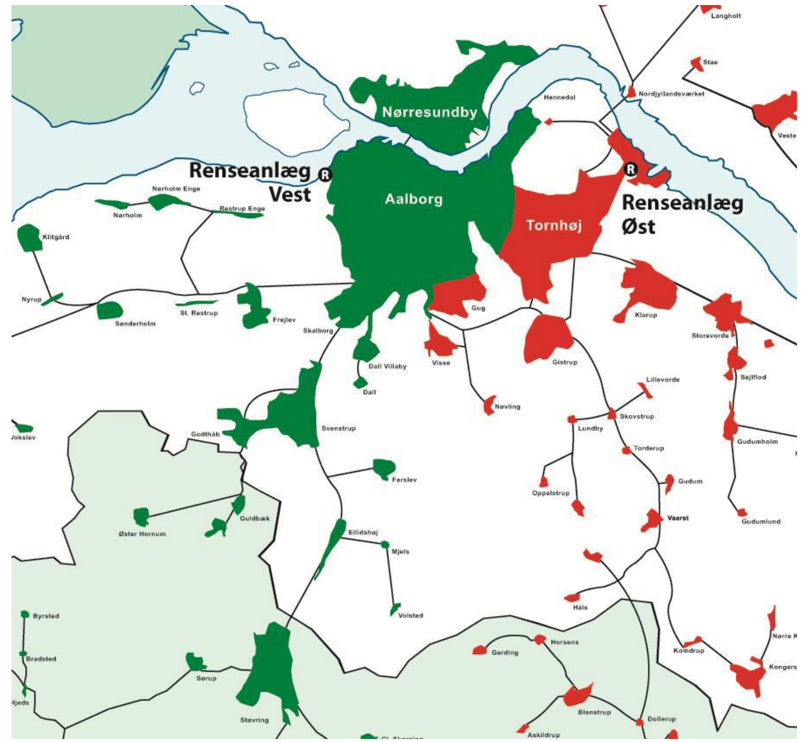
- ***Membranes.*** Various monotube active layers such as on macroporous α-alumina support (~100nm) were used was used.

- ***Analysis.*** The total ions and specified toxic ions rejections were measured using **conductivity** measurements respectively. The type and the molecular size of removed organic compounds were determined using **pH**, full spectrum **UV** and size exclusion **HPLC**. Inorganic N-compound rejections were calculated by **N-autoanalyzer**. Bioassays were done with ***Daphnia magna*** method.

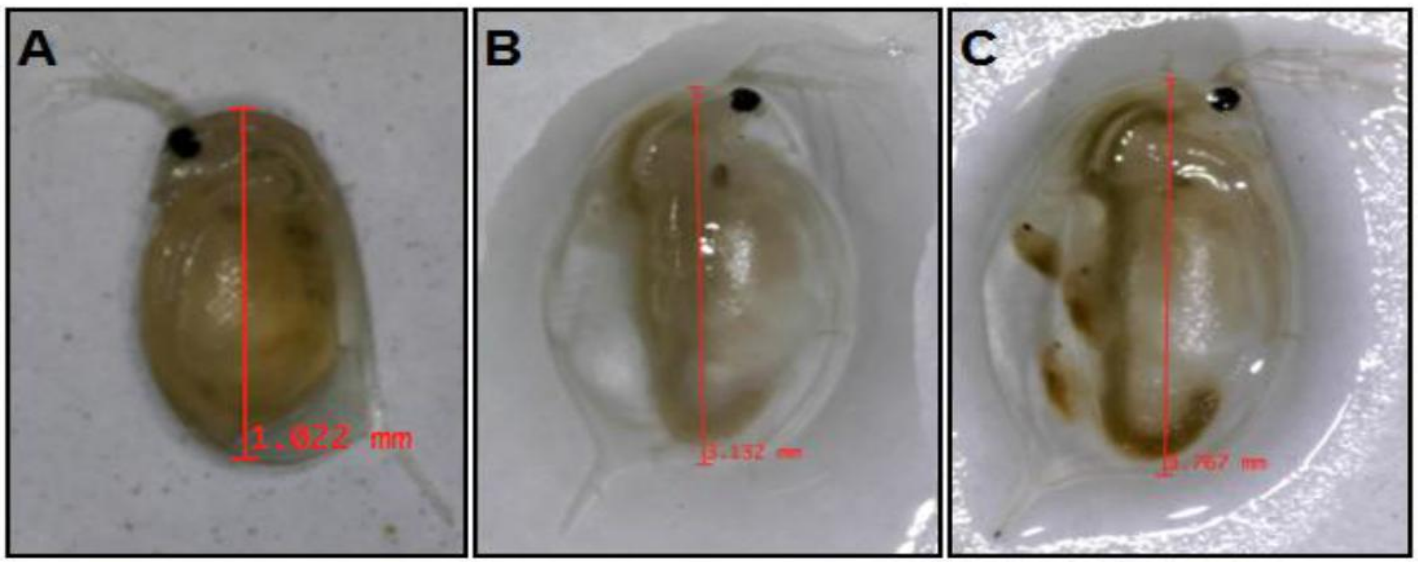
- ***MBR.*** *The MBR Pilot plant is already working in the WWTP site.*


Denmark
50 km
50 miles
Skaggerak
Frederikshavn
Alborg
Laeso
Kattegat
Viborg
Randers
Herning
Jutland
Arhus
Horsens
Vejle
Copenhagen
Fredericia
Sjaelland
Esbjerg
Kolding
Odense
Fyn
Svendborg
North Sea
Lolland
Falster
Mon


Gothenburg
Jönköping
Hjørring
Frederikshavn
Aalborg
Nykøbing
Viborg
Randers
Grenaa
Halmstad
Aarhus
Helsingborg
Kristianstad
Copenhagen
Malmö
Denmark
Wastewater Treatment Plant West


Nørresundby
Renseanlæg Vest
Aalborg
Tornhøj
Renseanlæg Øst

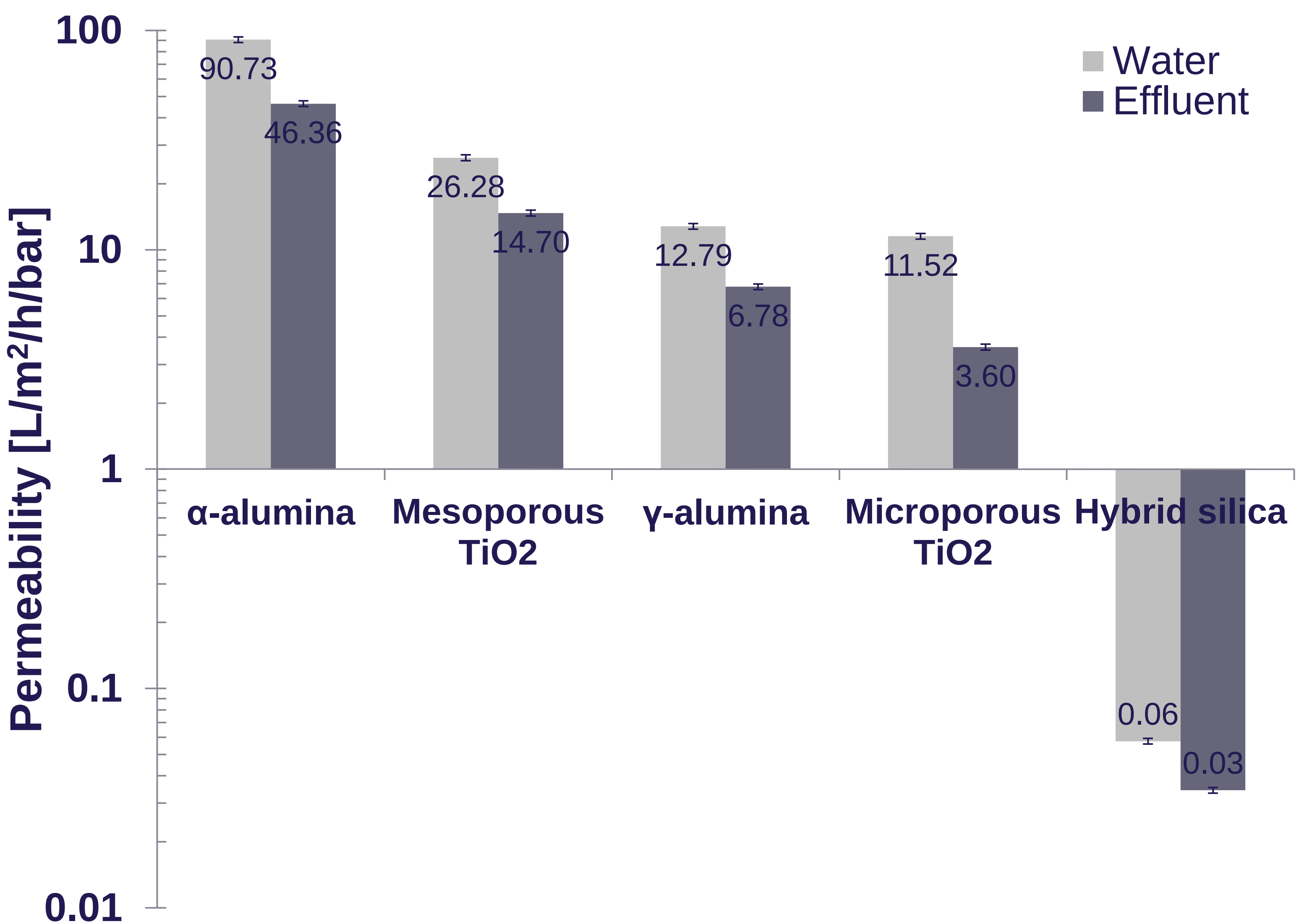
Material	Type	Nominal Main Pore size
α-alumina	MF- Macroporous	~100nm
TiO_2	UF-Mesoporous	15 nm
γ-alumina	NF- Mesoporous	5 nm
TiO_2	NF- Microporous	1 nm
Hybrid silica	RO-Microporous	<1nm

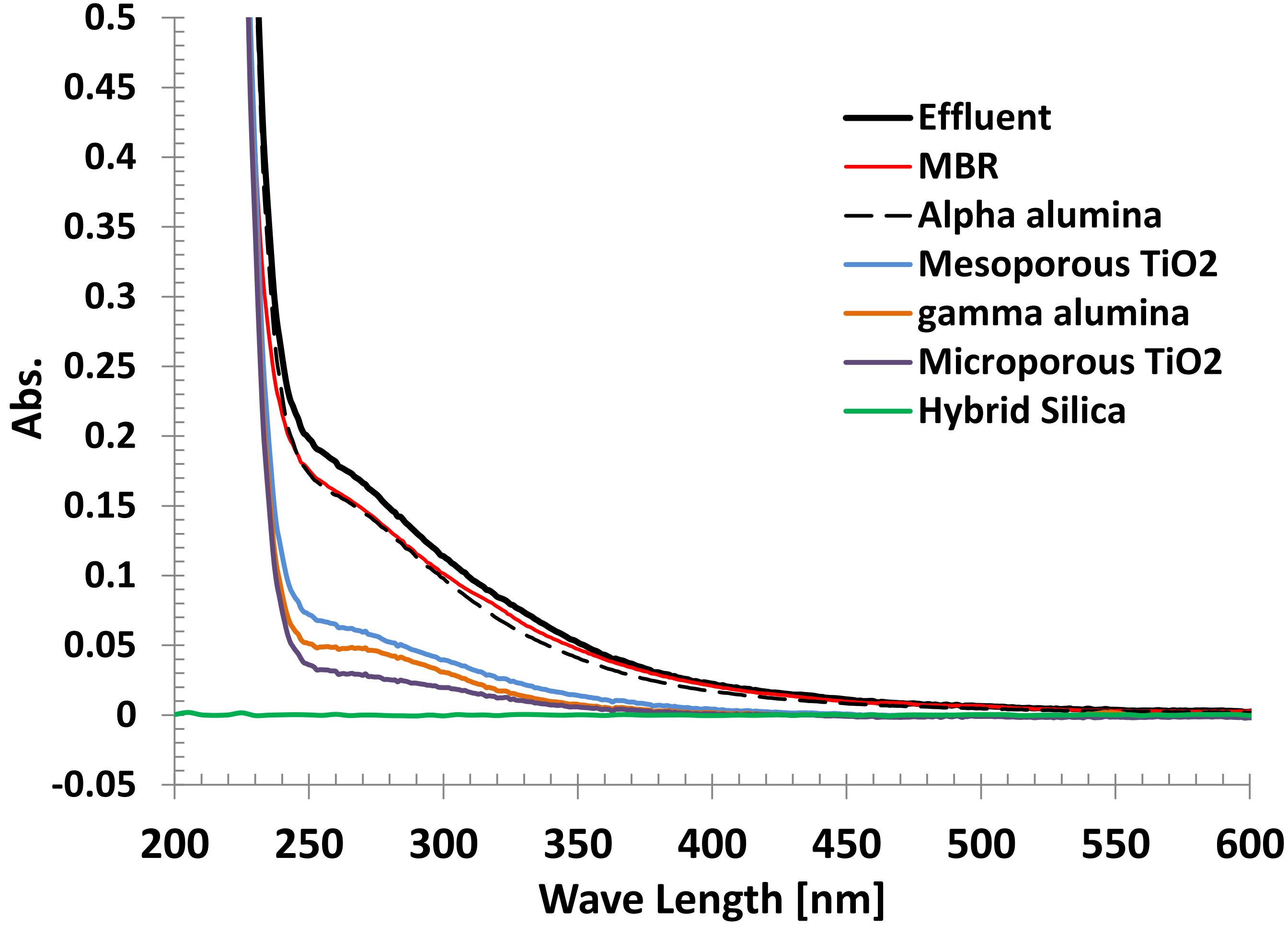


Before the test
Size: 1.022 mm

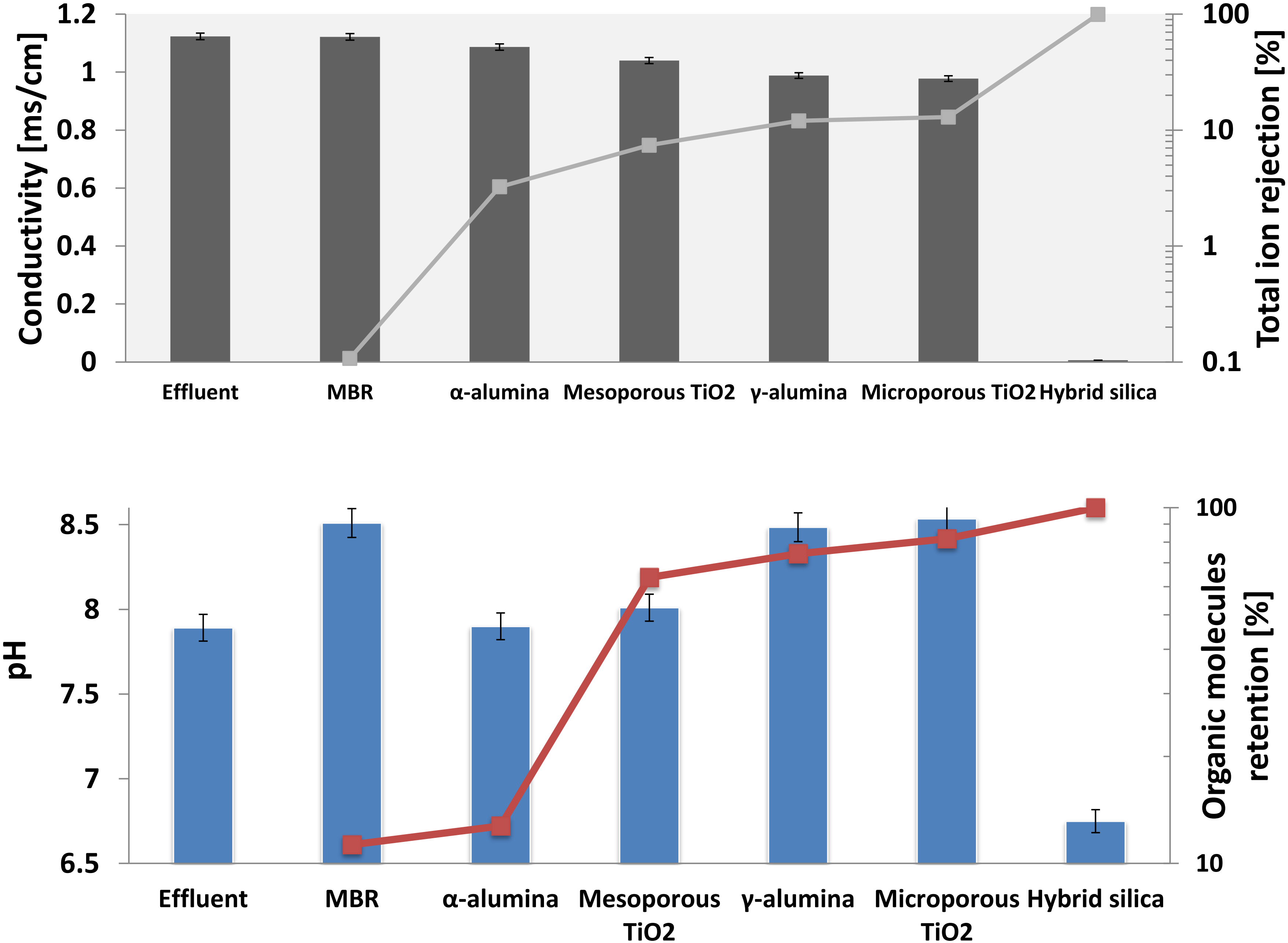
Water, after 21days
Size: 3.132 mm (A_0)

Sample after 21days
Size: 3.8 mm (A_1)

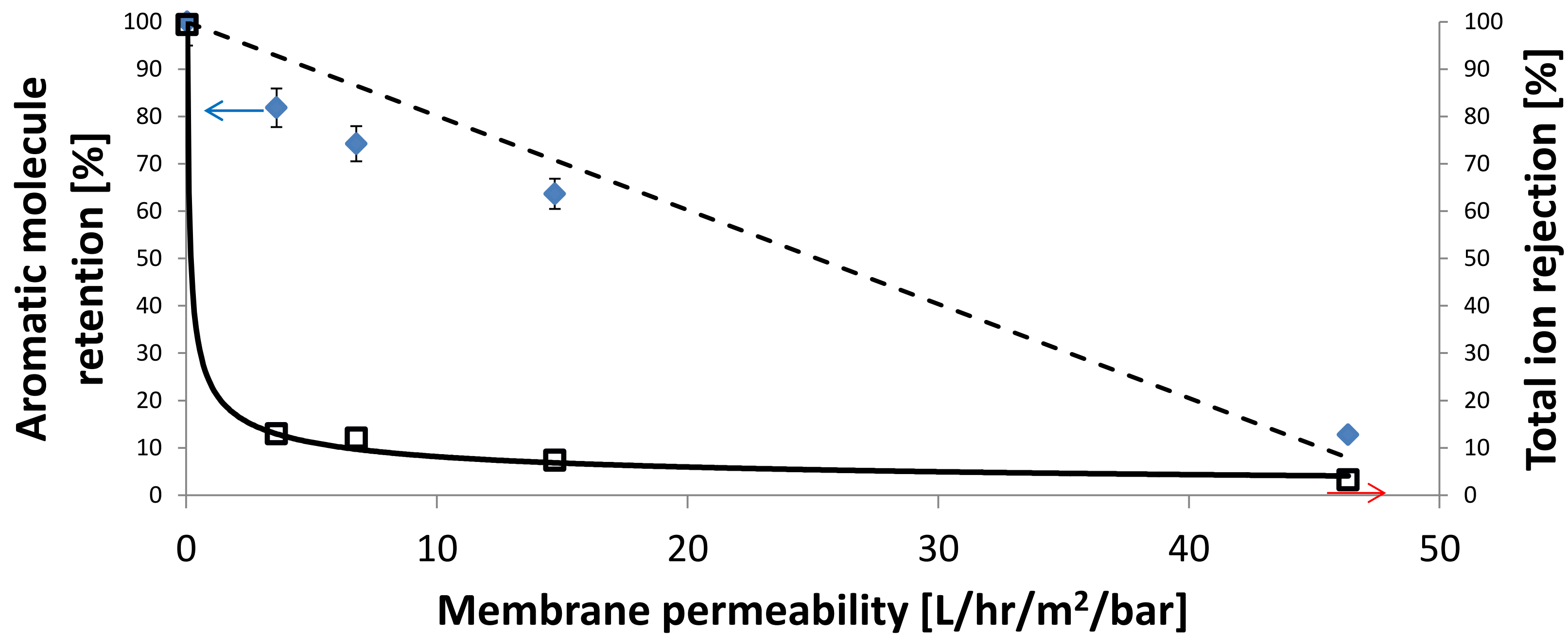

Permeability [L/m²/h/bar]
100
10
1
0.1
0.01
Water
Effluent
90.73
46.36
26.28
14.70
12.79
6.78
11.52
3.60
0.06
0.03
α-alumina
Mesoporous TiO2
γ-alumina
Microporous TiO2
Hybrid silica

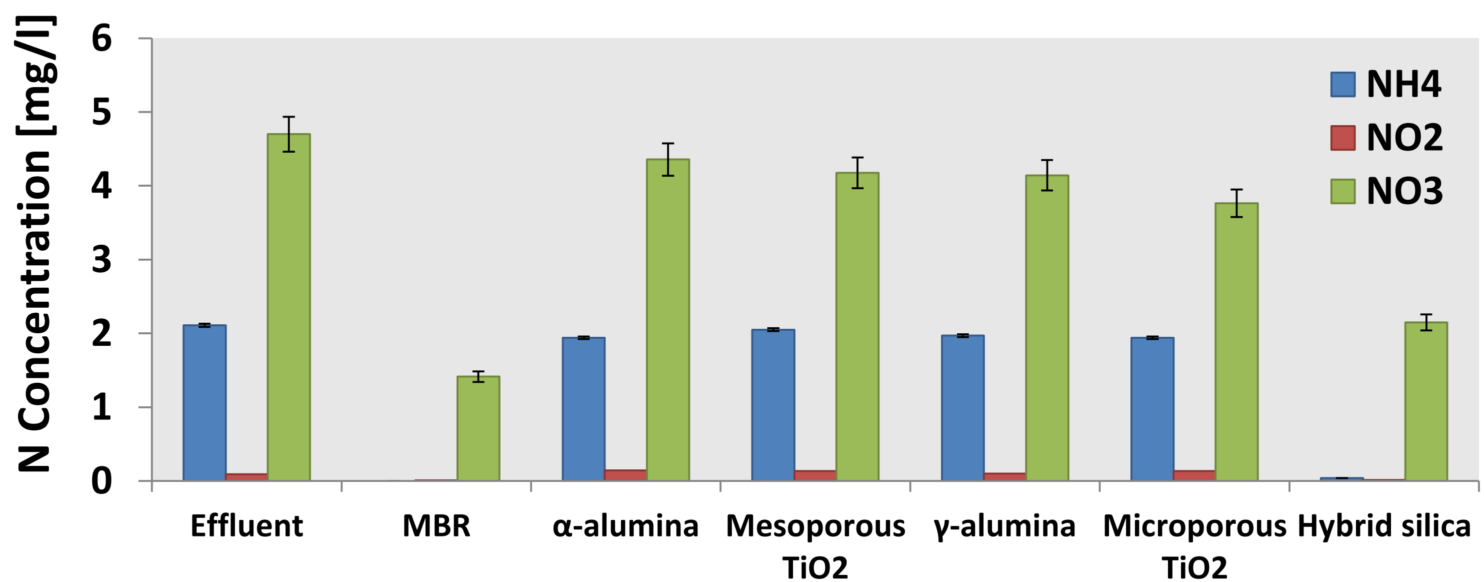


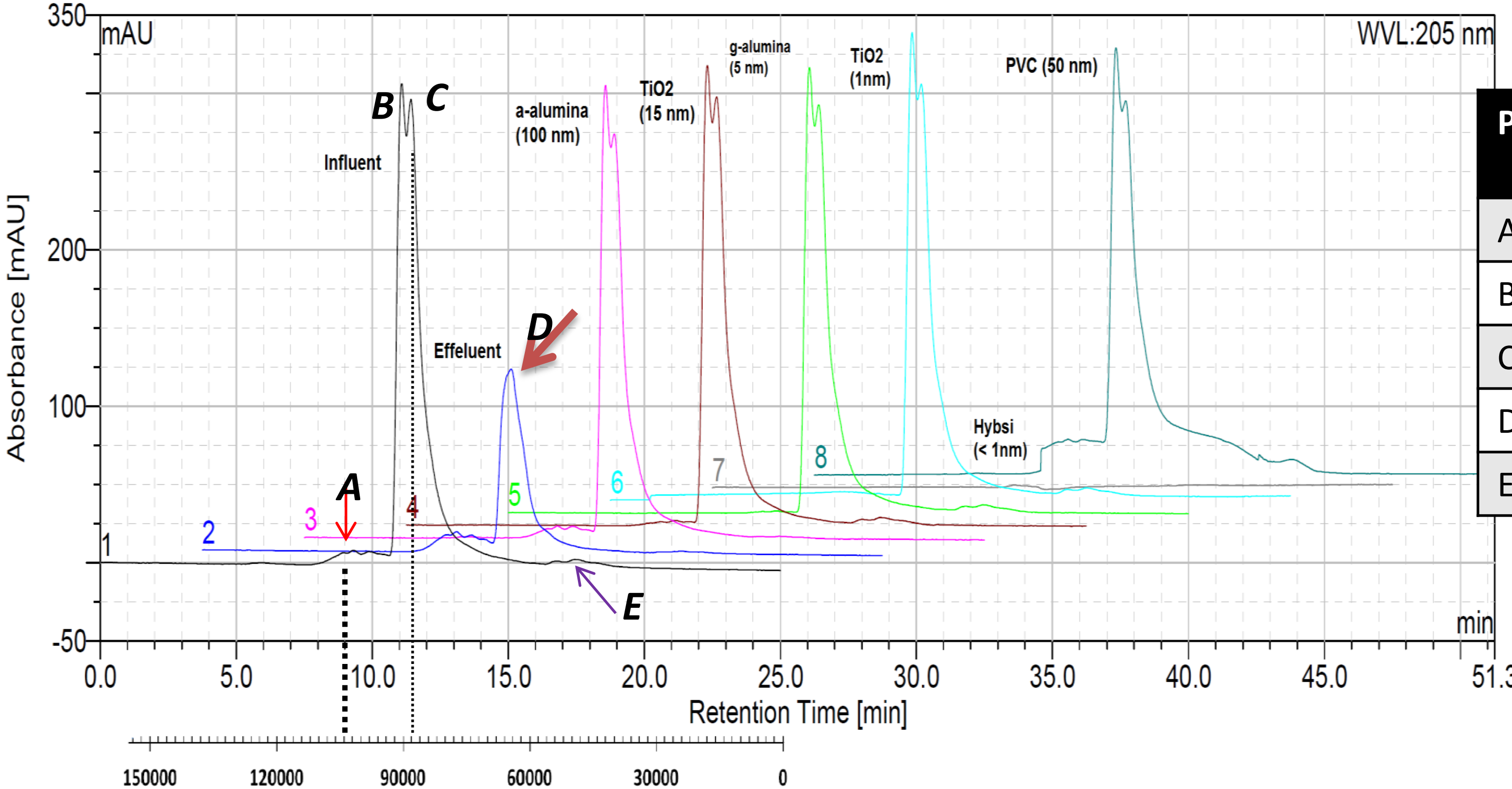
Abs.
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
200
250
300
350
400
450
500
550
600
Wave Length [nm]
Effluent
MBR
Alpha alumina
Mesoporous TiO2
gamma alumina
Microporous TiO2
Hybrid Silica



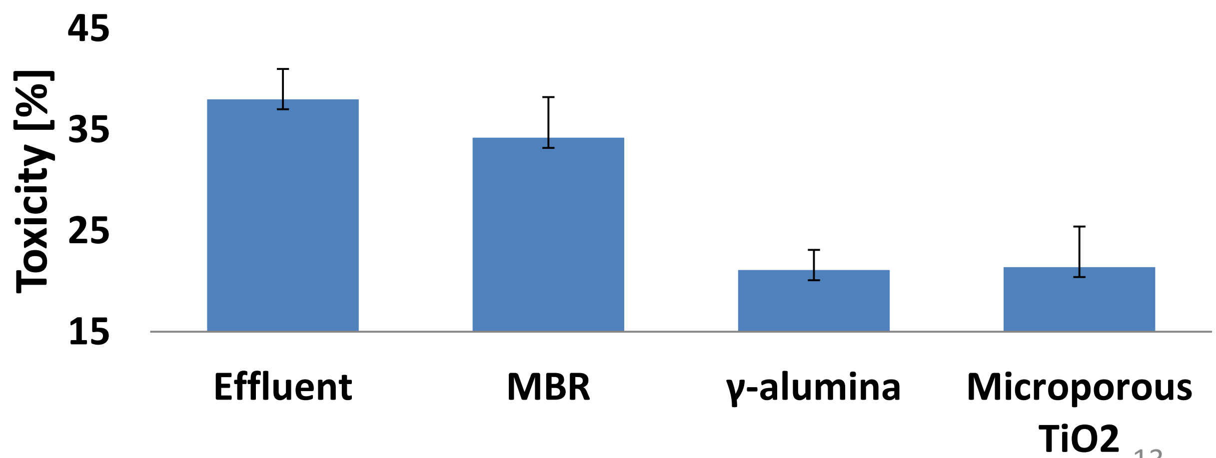
Conductivity [ms/cm]
Total ion rejection [%]
1.2
1
0.8
0.6
0.4
0.2
0
100
10
1
0.1
Effluent
MBR
α-alumina
Mesoporous TiO2
γ-alumina
Microporous TiO2
Hybrid silica
pH
Organic molecules retention [%]
8.5
8
7.5
7
6.5
100
10
Effluent
MBR
α-alumina
Mesoporous TiO2
γ-alumina
Microporous TiO2
Hybrid silica


Aromatic molecule retention [%]
Total ion rejection [%]
Membrane permeability [L/hr/m²/bar]
0
10
20
30
40
50
60
70
80
90
100


N Concentration [mg/l]
NH4
NO2
NO3
Effluent
MBR
α-alumina
Mesoporous TiO2
γ-alumina
Microporous TiO2
Hybrid silica
0
1
2
3
4
5
6



Peak	MW (KDa)
A	100
B	90
C	85
D	90
E	40



CONCLUSIÓN

- **Hybsi** active layer (<1nm, RO) could remove most of inorganic ions and organic molecules and increase the water quality up to drinkable water. But its permeability is very low (0.03 LMH/B).
- **α-alumina** (>100 nm, MF) did not shows a better performance for removing organic compounds and ions rejections.
- **Mesoporous TiO_2** (15nm, UF), **γ-alumina** (5 nm, NF) and **microporous TiO_2** (1nm, NF)could remove most of the aromatic organic compounds more than **MBR** but their ion rejections are not obvious (less than 10%).
- Chromatography results showed that MBR could remove a range of organic components (around 90 KDa) **even** better than NF ceramic membrane.
- MBR shows a better performance in competition with all ceramic membrane to remove N-compounds.
- Bioassays with ***Daphnia magna*** suggested that effluent polishing with γ-alumina membrane reduced toxicity of the treated water better than MBR and even TiO_2 micro porous membrane.
- Our study showed that **γ-alumina** is the optimized membrane for this application.

TIPS OF DAY:

"EXPERIMENTAL DESIGN IS FUNDAMENTAL FOR THE DEVELOPMENT OF NEW MEMBRANE APPLICATION"

THANK YOU FOR YOUR ATTENTION.

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